CDF tests for nonstandard top quark production and decay

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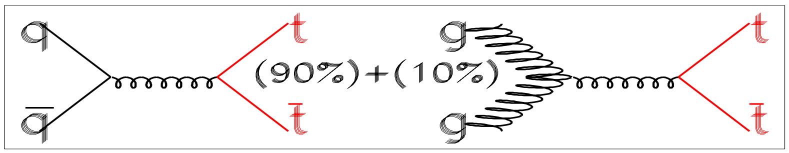
Outline

- This talk contains three independent CDF tests for non-standard top
  - Top quark p_T spectrum measurement: $d\sigma(t\bar{t})/dp_T$
  - W boson helicity in top decays
  - check for the top like particle with charge +4/3

Top Production at the Tevatron

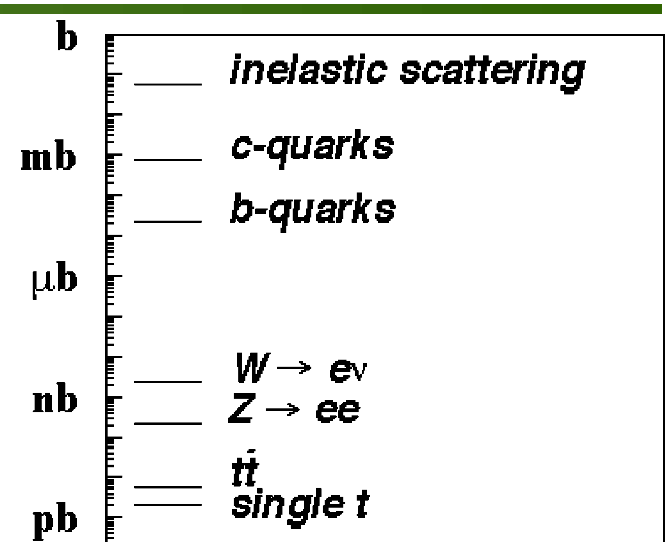
- Pair Production: $p\bar{p}\rightarrow t\bar{t}$

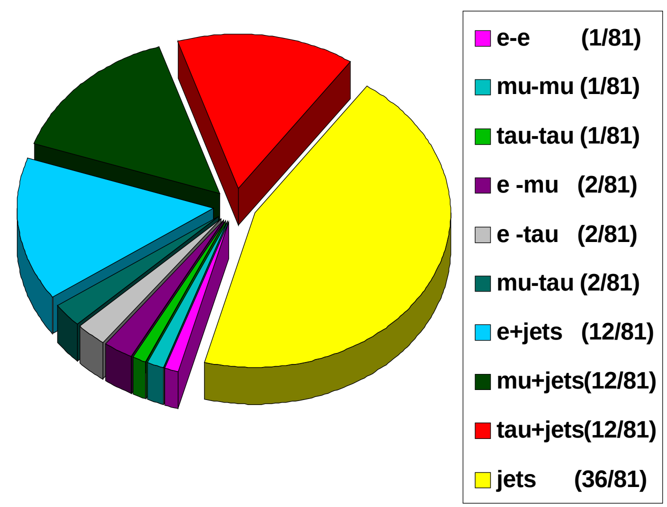


- Production of the single top through

Wg fusion and W * ~ 30% of σ(tt)

- BR(t Wb) ≅100 %
  - Both W's decay via W →lν
    - ✔ final state: lν lνbb - **DILEPTON**
  - One W decays via W →lν
    - ✔ final state: lν qq bb - **LEPTON+JETS**
  - Both W's decay via W →qq
    - ✔ final state: qq qq bb **ALL HADRONIC**



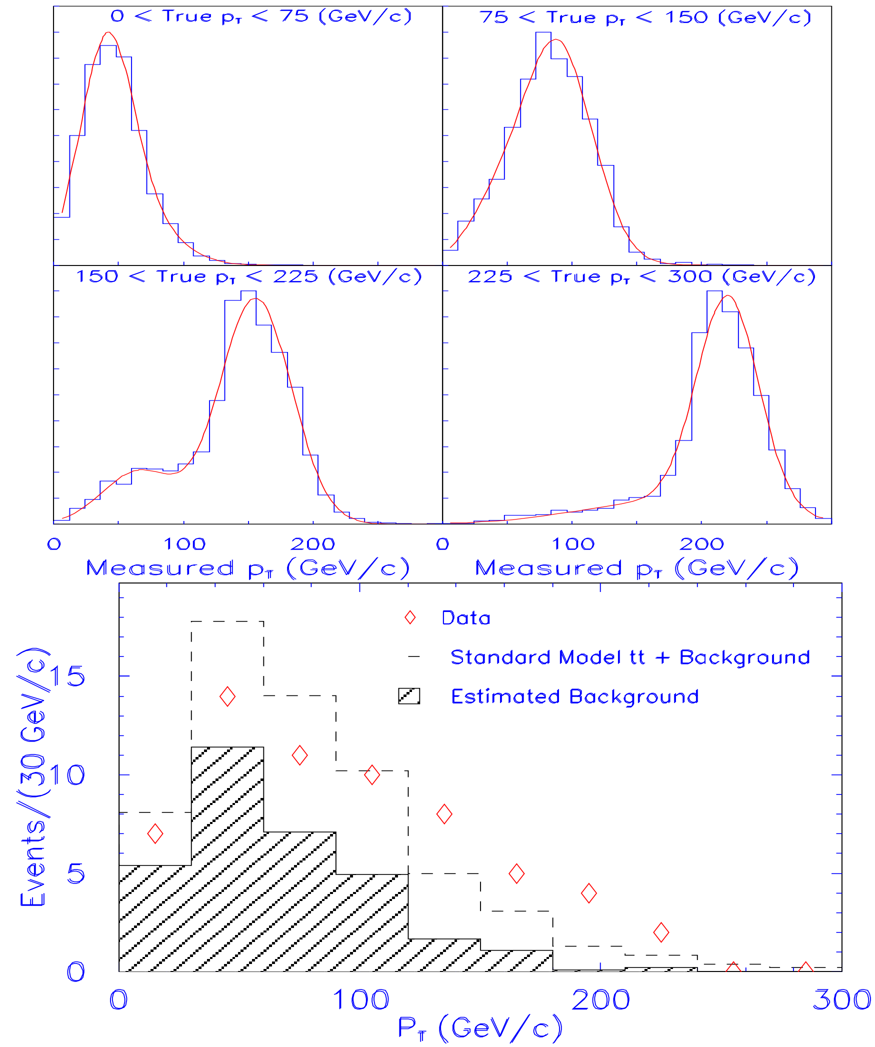


Top Quark p_t

- The idea is to check a number of theoretical investigations for alternative $t\bar{t}$ production mechanism
- Many exotic models predict - enhancement in the x-section for top with p_t>200 GeV/c
- CDF lepton plus jets events were used. Signature:
  - one central ($-1.1<\eta<1.1$), and Isolated high P_t>20 GeV/c lepton (e or μ)
  - missing E_T from the ν, (E_T>20 GeV)
  - 3 jets, E_T^{jet} > 15 GeV, $-2.0<\eta<2.0$
  - SECVTX, SLT or 4th jet, E_T^{jet} > 15 GeV, ($-2.0<\eta<2.0$),
- A kinematic fitter similar to the top mass measurement was employed: M_{top}=175 was constrained; events with χ^2>10 are rejected. 61 events form the final sample. The estimated background contribution: 31.9±4.6 ev.
- The p_t spectrum of the fully reconstructed hadronic top decay was used.

Top Quark p_t ,cont.

- Because of poor resolution and reconstruction effects the response function for every interval is introduced
- The unbinned LH fit to the measured p_t distribution is performed.
- The free LH parameters ($R_1,\ldots,R_4$) are the fraction of top quarks produced in true bins 1-4
- Performing KSM, the probability to observe a difference between the two distribution as large as the one that is measured is calculated to be 5 % (1% to 9.4% when the systematic effects changes 1σ)

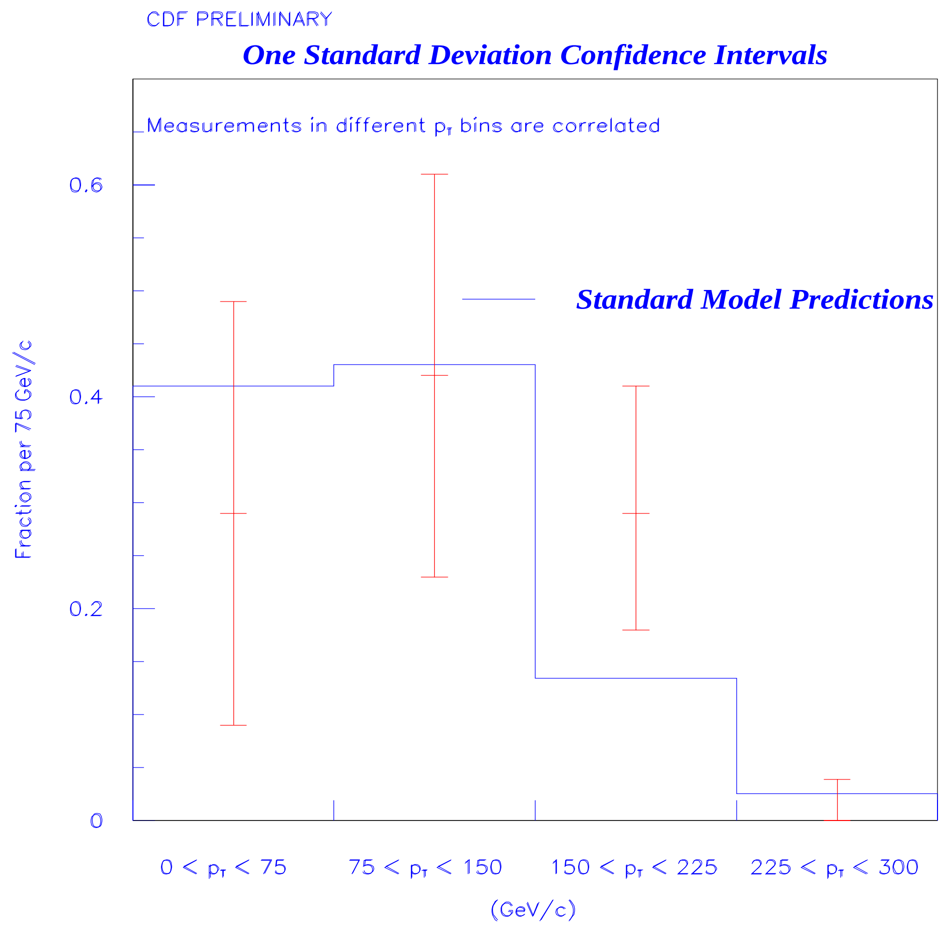


Top Quark p_t: result

$R_1 + R_2 = 0.66 \pm 0.17(\mathrm{stat}) \pm 0.07(\mathrm{syst})$ SM (0.84)

$R_4 < 0.16$ at 95% CL , SM (0.025)

p_T Bin	Parameter	Measurement	Standard Model Expectation
$0 \le p_T < 75$ GeV	R_1	$0.21^{+0.22}_{-0.21}(\mathrm{stat})^{+0.10}_{-0.08}(\mathrm{syst})$	0.41
$75 \le p_T < 150$ GeV	R_2	$0.45^{+0.23}_{-0.23}(\mathrm{stat})^{+0.04}_{-0.07}(\mathrm{syst})$	0.43
$150 \le p_T < 225$ GeV	R_3	$0.34^{+0.14}_{-0.12}(\mathrm{stat})^{+0.07}_{-0.05}(\mathrm{syst})$	0.13
$225 \le p_T < 300$ GeV	R_4	$0.000^{+0.031}_{-0.000}(\mathrm{stat})^{+0.024}_{-0.000}(\mathrm{syst})$	0.025
$0 \le p_T < 150$ GeV	$R_1 + R_2$	$0.66^{+0.17}_{-0.17}(\mathrm{stat})^{+0.07}_{-0.07}(\mathrm{syst})$	0.84



Run II: 3-4% accuracy!

W Helicity in Top Decays

- SM top - spin 1/2, V-A coupling
  - top quark decays to longitudinal (h_W=0) or left-handed (h_W=-1) W bosons

$$F_0 = \frac{\Gamma(h_w = 0)}{\Gamma(h_w = 0) + \Gamma(h_w = -1)} = \frac{1}{1 + 2M_w^2 / m_{top}^2} = 0.70\ for\ 175 GeV/c^2$$

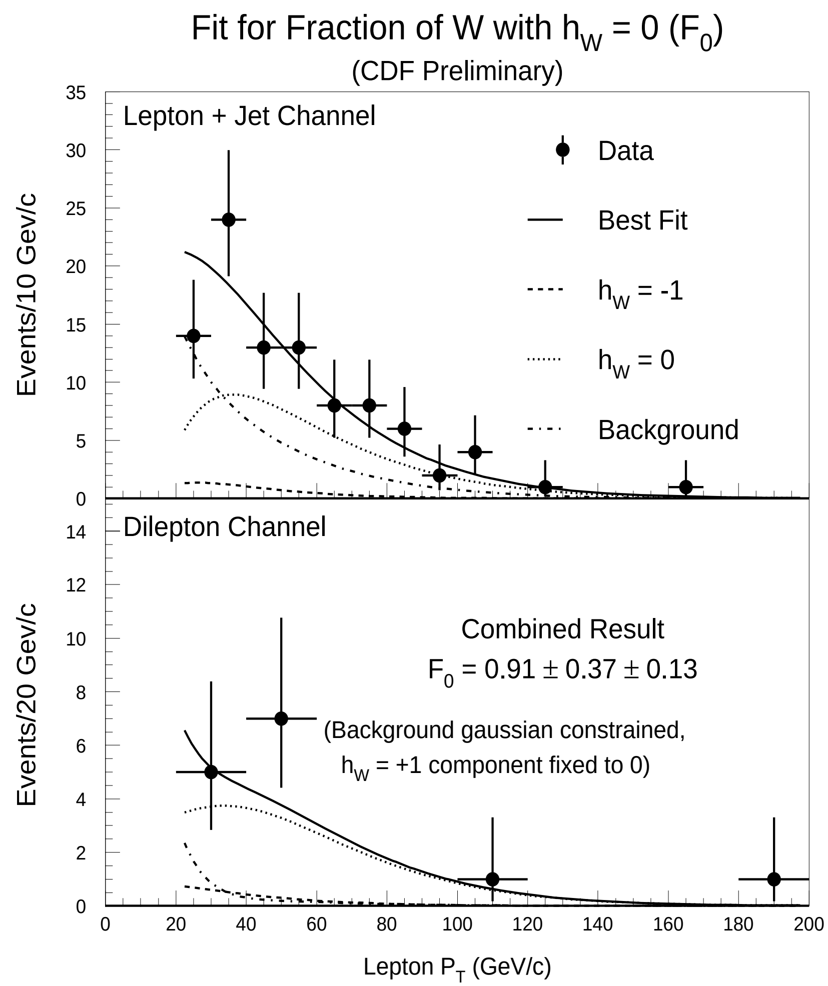
- The idea is to use F_0 as a probe for non-universal t-W-b couplings
- Lepton p_t distribution in $t \rightarrow bl\nu$ distinguishes the helicity states.
  - h_W = 0 corresponds to the hard p_t
  - h_W = -1 corresponds to the soft p_t
- CDF lepton plus jets events were used. Additional requirements:
  - at least one jet must be tagged by SECVTX
  - SLT sample has to have 4th jet, E_T^{jet} > 8 GeV, ($-2.4<\eta<2.4$)
  - notag sample, at least 4 jets, E_T^{jet} > 15 GeV, ($-2.0<\eta<2.0$)
  - total amount of leptons is 94

W Helicity in Top Decays, F_0

- Dilepton sample of 7 events generates 14 leptons
- Total number of cases is 108.
- The unbinned LH fit was performed to compare data and MC

$F_0 = 0.91 \pm 0.37(\text{stat}) \pm 0.13(\text{syst})$

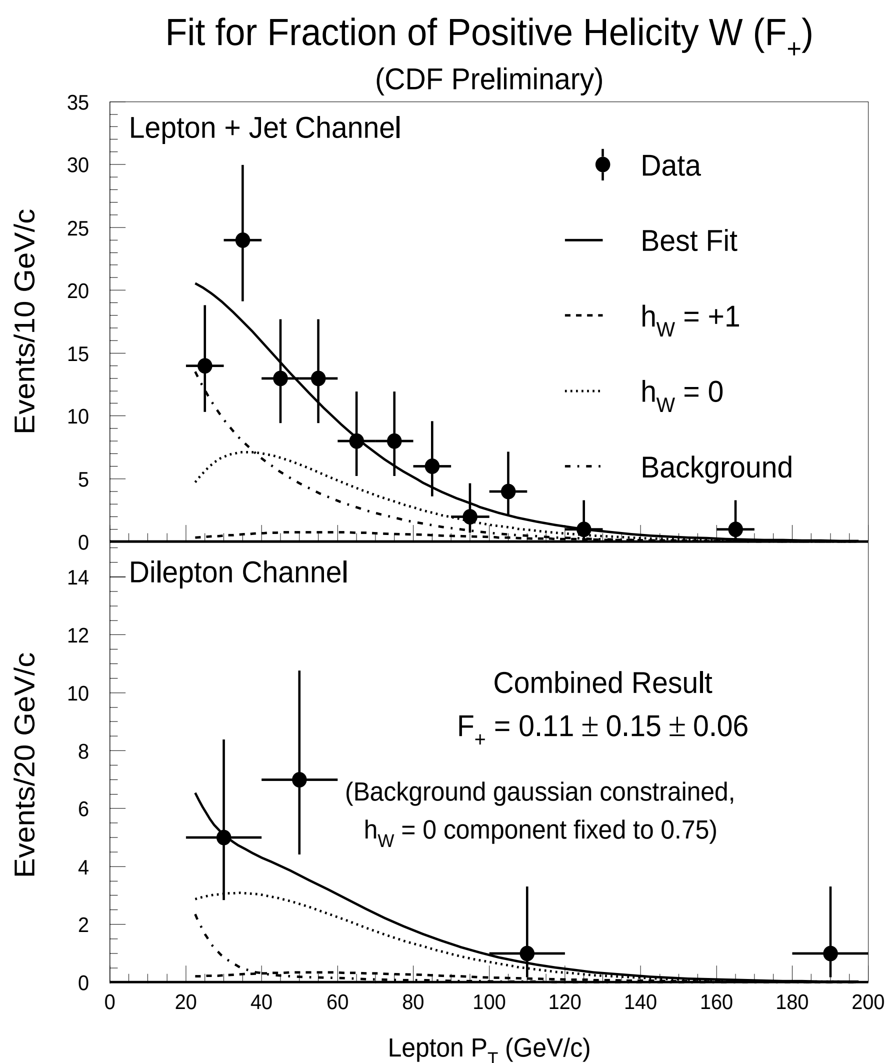
- Run II: F_0 - 4% accuracy



W Helicity in Top Decays, F_+

- A check for V+A coupling (F_{+1}) component was done by repeating the fit with F_0 constrained to SM value of 0.7

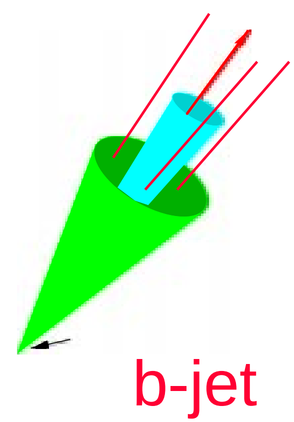
F_{+1}=0.11±0.15(stat)±0.06(syst)

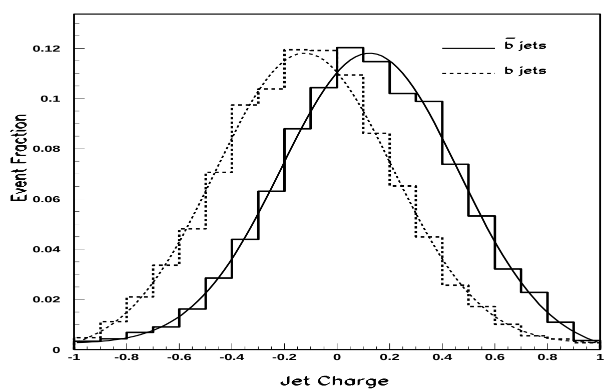


“Top” with charge +4/3

- **In case of SM ttbar events we have:**
  - $t \longrightarrow W^{+}\bar{b}$ and $\bar{t} \longrightarrow W^{-}b$
- **At the first top Thinkshop (Ernest Ma), it was announced the idea of alternative interpretation of the Tevatron top events (UCRHEP-T237)**
- **The idea is that the signal could be due to quark with charge 4/3 and mass around 175 GeV/c² which decays X** $\longrightarrow W^{+}\bar{b}$
- **I did an attempt to check this idea and to determine which hypothesis is more probable using CDF Run 1 data.**
- **Single and double tag data samples from Run1 were used. The jet charge is defined as**

$$C = \frac{\sum_{i=1}^{ntracks} q_i \cdot (\vec{p}_i \cdot \vec{e}_i)^k}{\sum_{i=1}^{ntracks} (\vec{p}_i \cdot \vec{e}_i)^k}$$





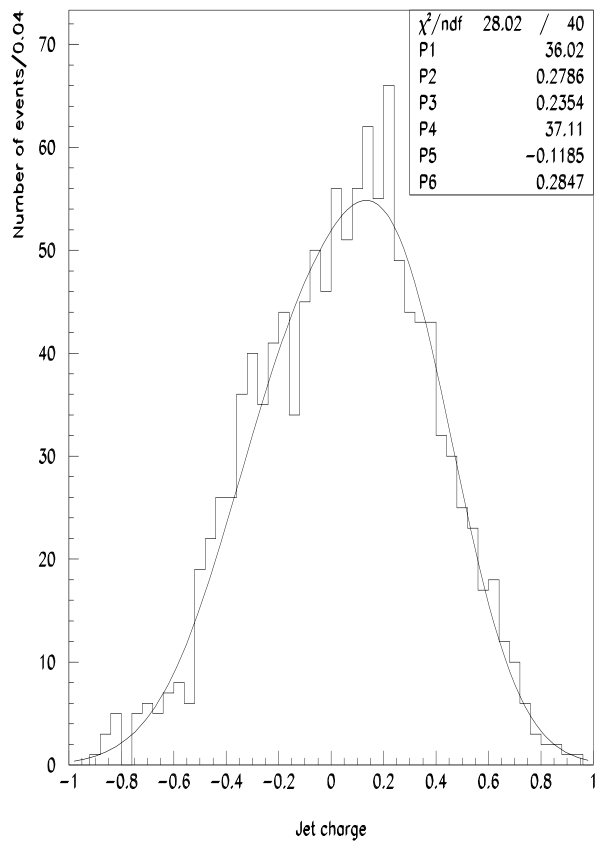
Event selection

- From the mass fitter we used only combinations in which the tagged jet corresponded to b-quark.
- For the tagged events we applied the selection

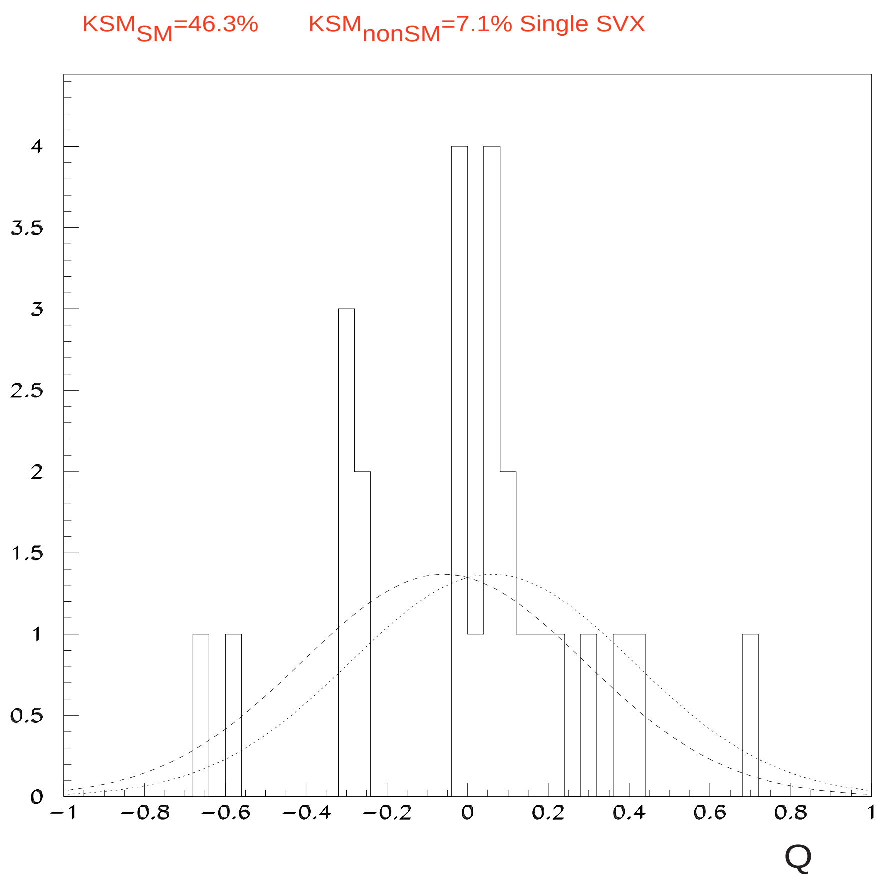
$$\min(|m_{top} - 175|/\sigma_{parabolic})$$

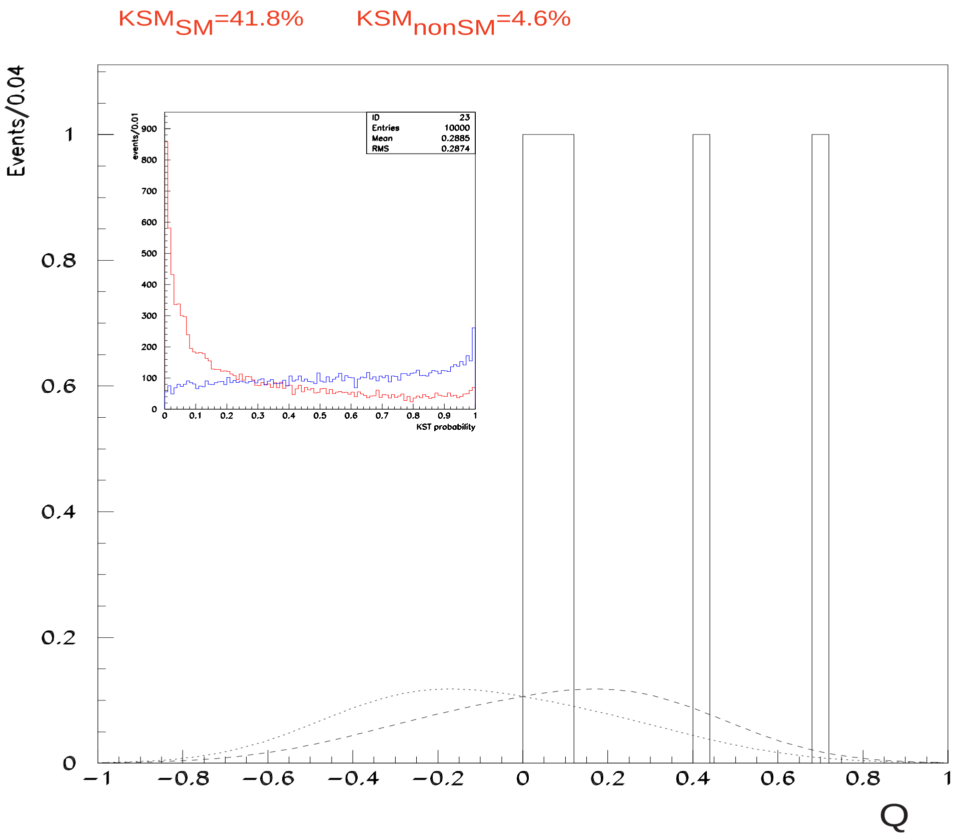
to increase the probability to pick up the correct combination

- We create a distribution $Q=\pm q_{lepton} x q_b$ (+ when tagged jet is in hadronic part, - when tagged jet is in the leptonic part).
- We used KS test to check both hypotheses



Run I result


KSM_SM=46.3%
KSM_nonSM=7.1% Single SVX
Q


KSM_SM=41.8%
KSM_nonSM=4.6%
Events/0.04
Q
KST probability

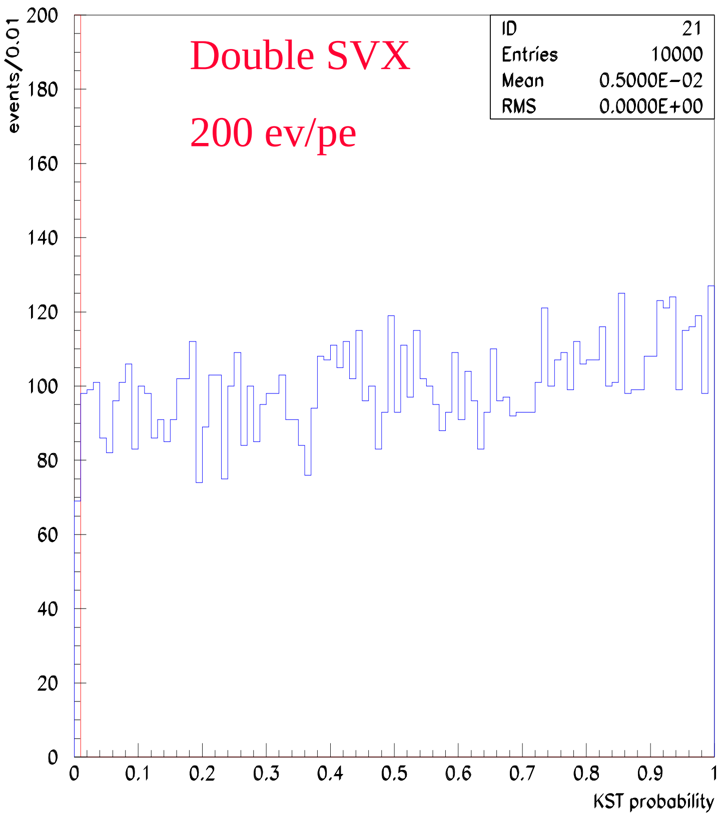
Run I result, cont.

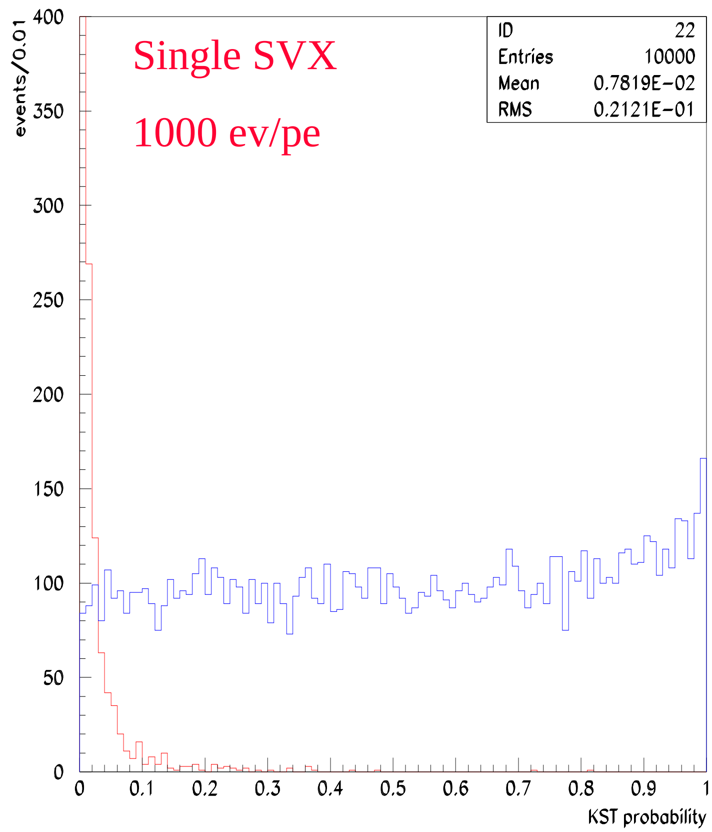
- Assuming MC model is correct, the probability to observe a difference between the two distribution as large as the one that is measured is calculated to be 41.8% (4.6%) in case of SM (nonSM). The similar numbers were obtained from single SVX data 46.3% (7.1%).
- To convert these numbers into probability ensemble tests (pseudo experiments (PE)) are performed. The result is:

$$\frac{P_{SM}^{doubleSVX}}{P_{nonSM}^{doubleSVX}} = 2.4$$

- Run II: 200 double SVX tagged events. We can check the hypothesis charge +2/3 vs charge +4/3 on the level of 1%.

Run II


Double SVX
200 ev/pe
ID 21
Entries 10000
Mean 0.5000E−02
RMS 0.0000E+00
events/0.01
KST probability


Single SVX
1000 ev/pe
ID 22
Entries 10000
Mean 0.7819E−02
RMS 0.2121E−01
events/0.01
KST probability

Summary

- All three measurements are more likely to be consistent with the SM predictions but the limited statistic still keeps a room for surprises.
- Run II data will give us possibility to perform precision measurements, increasing ~ 100 times the data samples.